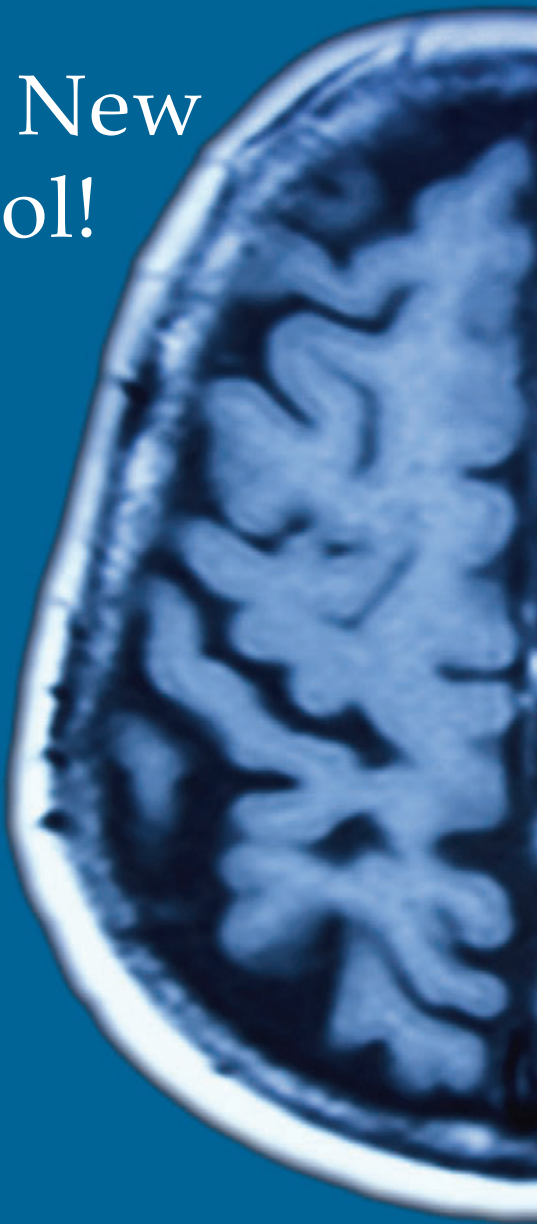
Introducing Functional Magnetic Resonance Imaging…

An Exciting New Research Tool!



American Psychological Association

Science Directorate

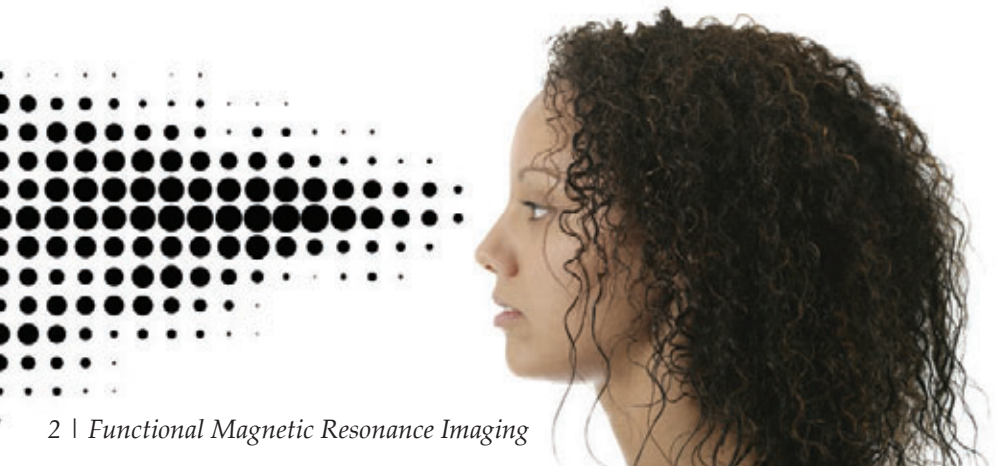
Imagine you had a device that allowed you to read people's minds.

A brain scanning technology called functional magnetic resonance imaging (fMRI) isn't quite a mind reader, but it comes close.

Regular MRI uses a powerful magnet and radio waves to make images of the brain or other structures inside your body. In the early 1990s, researchers thought up a new way to use this imaging technology: as a research tool rather than a diagnostic method. Putting the f in fMRI, these researchers focus on function. Using an MRI scanner, they watch how blood flows to different parts of the brain as people respond to a specific stimulus—a sound, an image, even a touch. While regular MRI results in snapshots of what's inside the body, fMRI produces movies starring the brain.

Psychologists and other researchers are using fMRI to do a whole lot more than just seeing what lights up in people's brains. They're using it to help answer classic questions within psychology. How do people make decisions? What's the best way to treat reading problems? Why is it so hard to stop smoking?

Although some people aren't convinced that extra blood flow to parts of the brain actually means something, many psychologists are combining data from brain scans and people's actual behavior to search for answers to these and other questions.



This booklet gives examples of how psychologists and other researchers are using fMRI. The booklet has four sections: improving lives, treating disorders, addressing social problems, and exploring the mind. The examples aren't meant to be a complete list of everything psychologists are doing with fMRI. We've written them to grab your interest and introduce you to the world of fMRI-based research. There are even references to original studies you can look up if you want to dig deeper.

The material in this booklet should help you understand why psychologists and others are so excited about fMRI. We hope you'll get excited, too.

The American Psychological Association's Science Directorate produced this booklet, which was made possible by support through a grant (MH63140) from the National Institute of Mental Health.

MRI vs. fMRI

If you're having your brain scanned with MRI, you lie on a table with your head inside a giant magnet. Protons inside the atoms in your brain line themselves up with the magnetic field, only to be whacked temporarily out of alignment with a pulse of radio waves aimed at your head. As your protons relax back into position again, they themselves emit radio waves that a computer uses to create a brain snapshot. With fMRI, researchers rely on two more facts about your body: the fact that your blood contains iron and the fact that your blood rushes to specific parts of your brain as they're activated. As freshly oxygenated blood zooms into a region, the iron distorts the magnetic field enough for the scanner to pick up.

Improving Lives

Boosting Moods

Can you train your brain to be happy?

Yes, says psychologist Richard Davidson. According to his research, meditation can help your brain learn to flex its happiness muscles. To study the impact of brain boot camp, Davidson turned to Buddhist monks from Tibet—the Olympic athletes of meditation.

Using fMRI to scan the brains of monks who had spent up to 50,000 hours meditating, Davidson and his colleagues found that meditation activated the area of the brain in charge of joy. But you don't have to spend half your life in meditation to see an effect. Even the study participants who were complete beginners saw changes in their brain activation. In short, you can improve your ability to be happy just like you can improve your basketball skills!

Of course, having a happiness-prone personality helps. Psychologist Turhan Canli has found that whether you see the glass as half full or half empty depends in part on your personality.

In one study, Canli and his colleagues tested participants to see if they were optimistic and sociable or anxious and insecure. The researchers then showed photographs of puppies, ice cream, and other positive things and photos of angry people, cemeteries, and other negative things to the participants while they lay in an fMRI scanner.

They found that the optimistic participants' brains reacted more strongly to the positive images, while the anxious participants' brains reacted more strongly to the negative.

Taking things one step further, psychologist Kevin Ochsner

has found that even people who aren't naturally happy can harness the power of positive thinking.

By making an effort to change the way you see something, Ochsner and his colleagues discovered, you can change the way your brain responds to it. If you see a woman crying outside a church, you might think "funeral." But if you instead view her tears as evidence of a joyful wedding, says Ochsner, you can calm the part of your brain that's the seat of distress.

Psychologists are using fMRI to do more than just study what goes on in the brains of people trying to get happy. Some believe the device itself can help people get there.

Psychologist Kalina Christoff, for example, hopes that one day people will be able to use real-time feedback from fMRI to stop having thoughts they don't want to have.

Neuroscientist Christopher deCharms, Christoff, and their colleagues have already found that with training and ongoing fMRI feedback, people can actually activate specific areas of their brains. They also found that participants were able to keep activating a specific brain region even after the fMRI information was no longer provided.

According to Christoff and her colleagues, this ability to watch yourself think could help patients with depression, schizophrenia, or other disorders regulate their brains. That's enough to make anyone happy!

Canli, T., Zhao, Z., Desmond, J.E., Kang, E., Gross, J., & Gabrieli, J.D.E. (2001). An fMRI study of personality influences on brain reactivity to emotional stimuli. *Behavioral Neuroscience, 115*, 33-42.

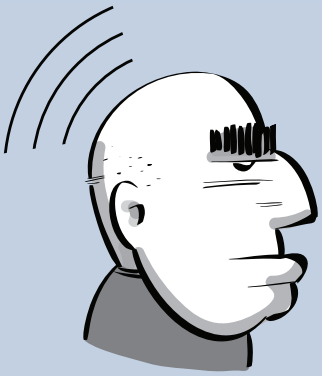
deCharms, R.C., Christoff, K., Glover, G.H., Pauly, J.M., Whitfield, S., & Gabrieli, J.D. (2004). Learned regulation of spatially localized brain activation using real-time fMRI. *Neuroimage, 21*, 436-443.

Lutz, A., Dunne, J.D., & Davidson, R.J. (In press). Meditation and the neuroscience of consciousness. In P.D. Zelazo, M. Moscovitch, & E. Thompson (Eds.), *The Cambridge Handbook of Consciousness*. Cambridge: Cambridge University Press.

Ochsner, K.N., Bunge, S.A., Gross, J.J., & Gabrieli, J.D.E. (2002). Rethinking feelings: An fMRI study of the cognitive regulation of emotion. *Journal of Cognitive Neuroscience, 14*, 1215-1229.

Bertino's Brain

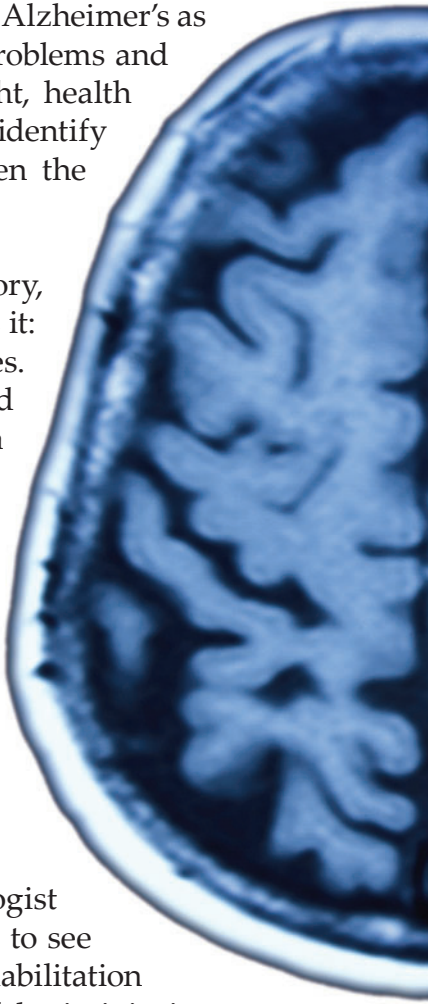
A 19th century Italian peasant named Bertino hurt his head so badly he wound up with a chunk of his skull missing and only a thin layer of tissue and skin covering the hole in his head. A researcher named Angelo Mosso noticed that whenever Bertino heard church bells ringing—a reminder that it was time to pray—the pulsations of his brain increased visibly. When Mosso asked him to multiply some numbers, the pulsations increased again. As a result, Mosso was the first to realize that the surge of blood to the brain could serve as an indicator of mental activity.



Preventing Disability

Doctors have long used MRI to diagnose tumors and other problems that can lead to disability. Now psychologists and other researchers are using fMRI to help prevent disability in the first place.

Psychologist Stephen Rao, for instance, is hoping that he has found a way to spot a brain disease called Alzheimer's as much as 10 or 15 years before memory problems and other symptoms show up. If Rao is right, health professionals may one day use fMRI to identify people with Alzheimer's at a point when the disease is more treatable.



Rao's research focuses on long-term memory, and he uses an unusual method to assess it: the brain's ability to recognize famous faces. In one study, Rao and his colleagues found that pictures of famous faces prompt a flurry of activity in specific areas of the brain. And since these areas are the first to be attacked by Alzheimer's, a lack of activity in these regions could signal the very beginnings of disease.

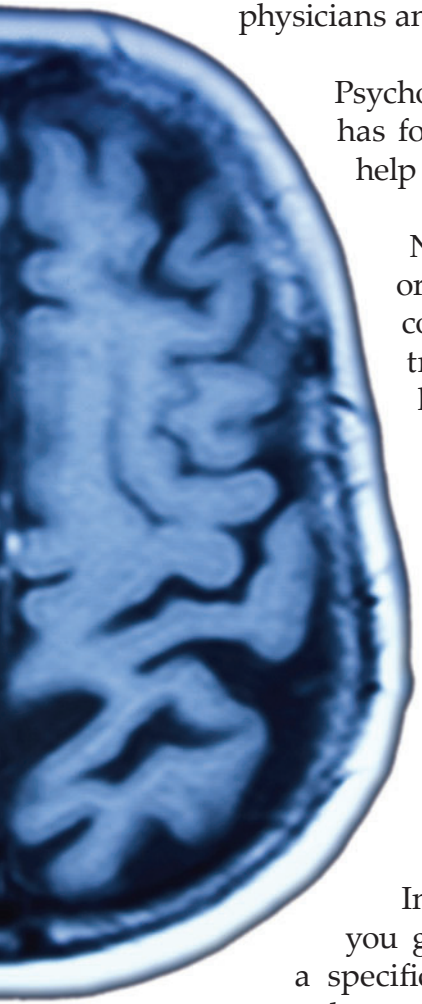
Psychologists and other researchers also use fMRI to see how well rehabilitation is working in people who already have problems.

In one study, for instance, psychologist Linda Laatsch and colleagues used fMRI to see how well a treatment called cognitive rehabilitation therapy works for people who have had brain-injuring accidents. In this therapy, patients do activities that help them regain their thinking skills and learn new ways of doing things.

In the study, Laatsch and her colleagues focused on patients who needed help with reading after having a snowboard crash, getting hit

in the head by a baseball, or having some other kind of accident. The researchers scanned patients' brains, put them to work on increasingly difficult reading tasks, then scanned their brains again. They found changes in both the extent and pattern of activation within patients' brains, suggesting that the therapy was successful.

Psychologists are working with surgeons as well as physicians and rehabilitation specialists.



Psychologist Kathleen McDermott, for example, has found a possible new way to use fMRI to help guide surgeons' scalpels.

Neurosurgery for problems like tumors or epilepsy can put patients' ability to communicate at risk. As a result, surgeons try to identify parts of the brain that handle language before surgery so they can steer around them when they start cutting.

That can be a difficult task, since the exact location of such regions is different in every patient. Current mapping methods provide only a general sense of where those regions are.

The potential alternative that McDermott has developed draws on seemingly unrelated research she has done on memory.

In that research, she has found that if you give people a list of words that relate to a specific topic—"bed," "rest," and "awake," for example—or that simply sound alike—"beep," "weep," and "heap"—they tend to think they've heard a related word like "sleep" even when they haven't. That's because thinking about one idea makes the brain start thinking about related ones, making people think they're remembering those concepts even though it's just that their brains have them ready to go.

Now McDermott thinks that surgeons can put this research to use. By presenting study participants with lists of words with similar themes and sounds and asking them to think about how they were related, the researchers found that they could identify individual variations in the location of language areas.

Although more research is needed, they believe an hour's worth of fMRI scanning will one day give surgeons the information they need to prevent this kind of disability.

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Leveroni, C.L., Seidenberg, M., Mayer, A.R., Mead, L.A., Binder, J.R., & Rao, S.M. (2000). Neural systems underlying the recognition of familiar and newly learned faces. *The Journal of Neuroscience, 20*, 878-886.

McDermott, K.B., Watson, J.M., & Ojemann, J.G. (2005). Presurgical language mapping. *Current Directions in Psychological Science, 14*, 291-295.

The Sad Tale of Phineas Gage

In 1848, a railway worker named Phineas Gage suffered a terrible accident: A heavy metal rod was blown right through his head. Amazingly, Gage survived. His sunny disposition didn't. Once a popular fellow, he underwent a dramatic personality change—for the worse—after the accident. What was bad for Gage was good for science, however. His experience provided some of the earliest evidence that damage to certain parts of the brain could change someone's personality.

Treating Disorders

Overcoming Dyslexia

Say the sounds "ba" and "pa" super-fast, and you'll see that it's easy to get the two confused.

For as many as one in five people, it's worse than that. A learning disability called dyslexia makes it difficult for them to break words down into phonemes—the building blocks of language—and then to link those sounds with symbols on the page. As a result, reading and writing can be a huge challenge.

Dyslexia isn't a matter of bad eyesight, low intelligence, or poor education. Instead, the brains of people with dyslexia simply appear to be wired differently than those of other people.

Using fMRI to peer inside the skulls of children with reading difficulties and those with good reading skills, physicians and neuroscientists Bennett Shaywitz and Sally Shaywitz, along with a team of psychologists found that the better a child is at reading, the more activity there is in the left occipitotemporal region.

And while children with dyslexia can't rely on that specialized region, their brains do show extra activity elsewhere. To the researchers, that suggests that the children's brains were compensating for the problem area, just like you might use your left hand to write—however poorly—if your right hand got hurt.

Fortunately, people with dyslexia don't have to rely on such short-cuts. It turns out that dyslexic brains can be rewired!

One way to reprogram brains is by using a computer program called *Fast ForWord Language* developed by psychologists Paula Tallal and Steve Miller and neuroscientists Michael Merzenich and William Jenkins.

Drawing on fMRI research by Tallal and Miller, this fun program teaches kids how to really hear and process the different sounds that make up words. As children's skills get better, the program's "voice" talks faster and the words and sentences become more complex.

The program works, according to research by neuroscientist Elise Temple, psychologist John Gabrieli, and others. The researchers used fMRI to scan the brains of children with and without dyslexia. The children with dyslexia then spent 100 minutes a day using the *Fast ForWord* program during school. After eight weeks, the researchers scanned their brains again.

The good news? The children's brains had become more like those of the children who could read normally. In addition to having increased activity in previously under-active areas of the brain, the children also had increased activity in areas unassociated with reading.

There were big changes going on outside the fMRI scanner, too: The children improved their ability to read so much that they moved into the normal-scoring range on tests of reading ability.

Those kind of results have made the program very popular. Today hundreds of thousands of students across the US and as far away as India are using *Fast ForWord*. To try some examples of Fast ForWord exercises go to www.scientificlearning.com/examples.

Tallal, P. (2004) Improving language and literacy is a matter of time. *Nature Reviews Neuroscience, 5*, 721-728.

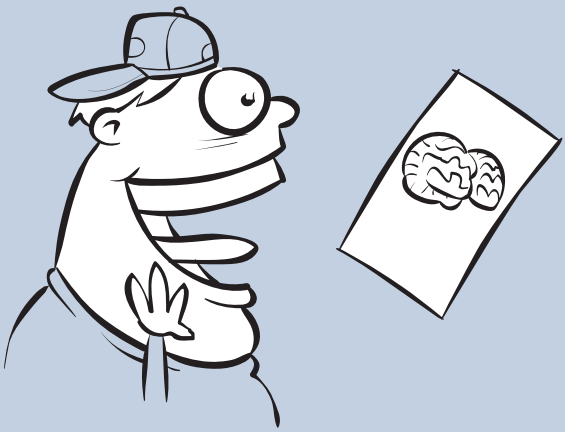
Shaywitz, S.E. (2003). *Overcoming dyslexia: A new and complete science-based program for reading problems at any level*. New York: Alfred A. Knopf.

Shaywitz, B.A., Shaywitz, S.E., Pugh, K.R., Mencl, W.E., Fulbright, R.K., Skudlarski, P., Constable, R.T., Marchione, K.E., Fletcher, J.M., Lyon, G.R., & Gore, J.C. (2002). Disruption of posterior brain systems for reading in children with developmental dyslexia. *Biological Psychiatry, 52*, 101-110.

Temple, E., Deutsch, G.K., Poldrack, R.A., Miller, S.L., Tallal, P., Merzenich, M.M., & Gabrieli, J.D.E. (2003). Neural deficits in children with dyslexia ameliorated by behavioral modification: Evidence from functional MRI. *Proceedings of the National Academy of Sciences, 100,* 2860-2865.

Imaging Kids

When researchers are scanning your brain with fMRI, you have to stay perfectly still or it won't work. How do researchers convince kids to stop wriggling? If you're Elise Temple, lead author of the Fast ForWord study, you use bribery. She offered kids Pokémon and baseball cards as rewards for good behavior. She also let them take home pictures of their brains.



Studying Autism

Shakespeare said the eyes are the windows to the soul. But for people with autism disorders, this doorway into social understanding is often closed.

Although autism disorders can produce problems ranging from social discomfort to extreme disability, what those with autism have in common is an overwhelmingly uncomfortable feeling when they look people in the eye.

Part of the problem is that people with autism don't seem to see a difference between people and objects.

In one study, for instance, psychologist Robert Schultz and colleagues presented photos of faces to individuals with and without autism. Using fMRI, they found that the brains of people with autism reacted differently to faces than the brains of those without the disorder. In normal brains, the sight of a face activates a region known as the fusiform face area. In brains of those with autism, Schultz found, that area doesn't show much activity but a nearby area involved in recognizing objects does.

When children with autism do look people in the eye, says psychologist Kim Dalton, they often see threats where there aren't any.

In one study, Dalton and her colleagues combined fMRI and eye-tracking technology to see what actually happens during eye contact.

They found that the amygdala—a part of the brain associated with negative emotions—becomes strangely active when children with autism gaze at a face. Thanks to the over-excited amygdala, even the most familiar face—their mom's or dad's, for instance—can seem scary. As a result, most people with autism avoid eye contact.

This difficulty in looking people in the eye can lead to extreme social disability, according to psychologist Simon Baron-Cohen. He has found that people with autism have a hard time making sense of the subtle and even not-so-subtle behavior of others.

In one study, Baron-Cohen and his colleagues showed photos of eyes to people with and without autism while they lay inside an fMRI scanner. As each set of eyes flashed by, the researchers asked participants to choose between two possible interpretations for what the person was feeling or thinking.

Do scowling eyes mean someone is friendly or unfriendly? For the most part, the people with autism couldn't say. And the scans showed that regions of the brain that seem to be in charge of so-called "social intelligence" became more active when people without autism searched the eyes for meaning, but stayed quiet for those with autism.

Now researchers are trying to find ways to help people with autism develop better social skills. Baron-Cohen and psychiatrist Ofer Golan, for instance, have found that people with autism can learn to recognize emotions better by using a software training program they created called *Mindreading*. To try out this program, visit www.jkp.com/mindreading.

Psychologist James Tanaka, in collaboration with Robert Schultz, has developed another software program to teach children with autism better social skills. This program is designed to teach how to tell the difference between faces and objects, read expressions, and

the like. Parents and teachers of children who have used the program report that it works, but Tanaka and others plan to use fMRI to see if the program is actually changing the children's brains.

The name of the program? *Let's Face It!*

Baron-Cohen, S., Ring, H.A., Wheelwright, S., Bullmore, E.T., Brammer, M.J., Simmons, A., & Williams, S.C. (1999). Social intelligence in the normal and autistic brain: An fMRI study. *European Journal of Neuroscience, 11*, 1891-1898.

Dalton, K.M., Nacewicz, B.M., Johnstone, T., Schaefer, H.S., Gernsbacher, M.A., Goldsmith, H.H., Alexander, A.L., & Davidson, R.J. (2005). Gaze fixation and the neural circuitry of face processing in autism. *Nature Neuroscience, 8*, 519-526.

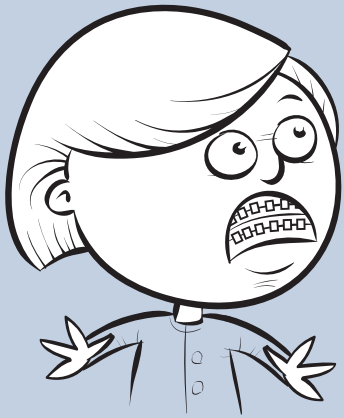
Golan, O. & Baron-Cohen, S. (2006). Systemizing empathy: Teaching adults with Asperger syndrome or high-functioning autism to recognize complex emotions using interactive multimedia. *Development and Psychopathology, 18*, 591-617.

Schultz, R.T., Gauthier, I., Klin, A., Fulbright, R.K., Anderson, A.W., Volkmar, F., Skudlarski, P., Lacadie, C., Cohen, D.J., & Gore, J.C. (2000). Abnormal ventral temporal cortical activity during face discrimination among individuals with autism and Asperger syndrome. *Archives of General Psychiatry, 57*, 331-340.

Tanaka, J., Lincoln, S., & Hegg, L. (2003). A framework for the study and treatment of face processing deficits in autism. In H. Leder and G. Swartzer (Eds.), *The development of face processing* (pp. 101-119). Berlin: Hogrefe Publishers.

Metal Detector

Because fMRI scanning involves magnets, any metal in the same room as the machine is a big no-no. That means no glasses, no hair clips, and no earrings. Braces and fillings in your teeth can also distort the images. Even tattoos can be a problem. In rare cases, the dyes used in tattoos contain a metallic ingredient that can heat up during the scan. Ouch!



Taming Addictions

A friend brings a big plate of cookies to the school bake sale. A nice chocolate cookie would sure taste good. But wait! Aren't you watching your weight?

If you can't resist cookies or other things that are bad for you, says psychologist Samuel McClure, it may be because emotion is conquering rationality in your brain.

McClure and his colleagues used fMRI to scan people's brains as they decided whether to choose a small reward right away or hold out for a larger reward later on.

The researchers discovered that immediate pleasures—such as a cookie—activated brain regions associated with emotion; delayed pleasures—such as the prospect of weight loss—activated regions associated with abstract reasoning. The emotional brain says, "Go for it!" The thinking brain says, "Hold on there!" If the emotional brain wins, you grab the cookie.

The mechanisms at work seem to be pretty much the same regardless of the temptation.

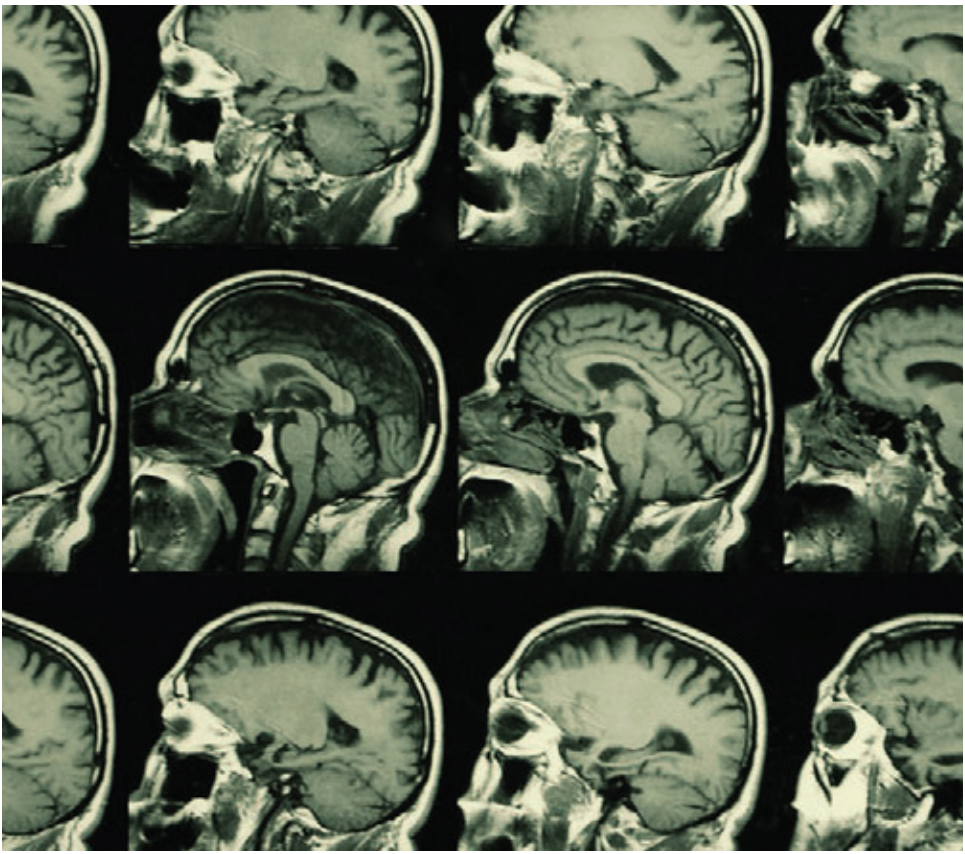
Psychiatrist Hans Breiter has found, for instance, that gambling and cocaine produce the same kind of activity in the brain.

In one experiment, Breiter and his fellow researchers used fMRI to see how people's brains reacted as they played a game of chance. (The study participants were just regular people, not people with gambling problems.) As participants waited to see where the game's

spinning arrow would land, the blood in their brains reacted just as it would to a rush of cocaine or some other intense pleasure.

Scientists are also exploring the use of fMRI to see who's at risk of falling back into bad habits after they manage to get their addictions under control. Psychologist Joseph McClernon, for instance, found that smokers' brains aren't all alike when it comes to resisting cravings.

McClernon and his colleagues asked smokers not to smoke overnight, then exposed them to pictures of people smoking as they lay inside an fMRI scanner. For some participants, going without smoking had no effect on their cravings or their brain activity. For others, however, going without smoking prompted both strong cravings and strong brain responses to the pictures. According to McClernon, the findings suggest that these smokers may have an especially hard time quitting and seeing smoking 'cues' might trigger their return to smoking.



His advice to these smokers? Throw away your ashtrays, stay away from other smokers, and do everything you can to avoid anything that reminds you of smoking.

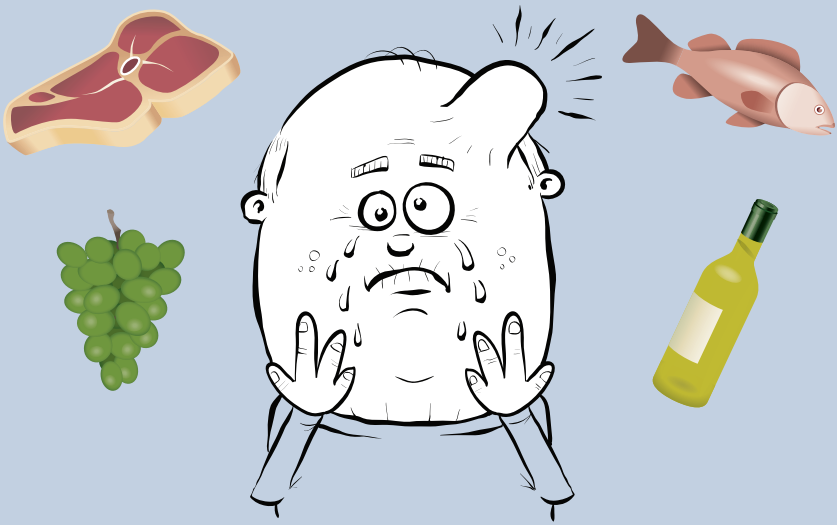
Breiter, H.C., Aharon, I., Kahneman, D., Dale, A., & Shizgal, P. (2001). Functional imaging of neural responses to expectancy and experience of monetary gains and losses. *Neuron, 30*, 619-639.

McClernon, F.J., Hiott, F.B., Huettel, S.A., & Rose. J.E. (2005). Abstinence-induced changes in self-report craving correlate with event-related fMRI responses to smoking cues. *Neuropsychopharmacology, 30*, 1940-1947.

McClure, S.M., Laibson, D.I., Loewenstein, G., & Cohen, J.D. (2004). Separate neural systems value immediate and delayed monetary rewards. *Science, 15*, 503-507.

Food for Thought

Suffer a stroke, brain tumor, or hit on the head, and you may develop an unusual problem called "gourmand syndrome." Marked by a nearly irresistible craving for fine food, this rare condition may be the result of damage to the part of the brain associated with controlling your impulses.



Addressing Social Problems

Battling Racism

How do you react when you meet someone of a different race? You may not be aware of what's really going on in your mind.

Research by psychologist William Cunningham and colleagues has revealed the complexity of what goes through people's minds when they look at photos of people of different races.

In their study, they scanned the brains of white people while flashing images of white and African American faces at them. Some photos flew by too quickly for people to consciously see them; others were presented slowly enough—about half a second each—to register.

Even though all of the study participants said they weren't prejudiced, their brains told a different story.

The super-fast images of African Americans prompted a lot of activity in the amygdala, a region of the brain associated with emotion. When the African American faces were shown more slowly, the amygdala calmed down and the activity shifted to a region of the brain associated with control and regulation. The findings suggest that the conscious mind can suppress unconscious prejudices.

But such repression takes a toll, according to a study by psychologist Jennifer Richeson and colleagues.

The researchers began by testing an all-white group of participants for racial bias, then had them interact with an African American person, and finally asked them to perform a test of their brain power. In a separate session, participants viewed photographs of the faces of unfamiliar African American men while the researchers used fMRI to watch their brain activity.

When they viewed the photos of the African American men, participants who had scored high on racial bias had high levels of activity in a brain region associated with the control of thoughts and behaviors. And participants with a lot of activity in that brain region performed more poorly on the test of thinking skills.

Are You Prejudiced?

Find out by taking the tests at www.implicit.harvard.edu. Developed by psychologist Mahzarin Banaji and other researchers, the tests can help you uncover your own hidden biases.

In a culture where it's not acceptable to be prejudiced, the researchers concluded, biased participants were struggling to suppress their true feelings. And just as your muscles get tired after you exercise hard, the effort of suppressing racial bias temporarily exhausts your brain power.

It's not just white people who respond negatively to African American faces, however.

In an fMRI-based study, psychologist Matthew Lieberman and colleagues found that African Americans themselves also have greater amygdala action when looking at black faces than when looking at white ones. Other researchers have speculated that whites have more amygdala response when viewing African American faces simply because they're not as familiar as white faces. Lieberman's research suggests that it's not unfamiliarity that explains the response, but learned cultural beliefs.

Fortunately, what's learned can be unlearned. Psychologist Elizabeth Phelps and colleagues, for instance, have found that familiarity with other racial groups may help defuse negative attitudes toward them.

In this research, Phelps exposed white participants to photos of unfamiliar white and African American men. The result? Greater

amygdala activity in response to the black faces. When the researchers substituted photos of well-liked, famous African Americans and whites, however, there was no difference.

When it comes to interactions between races, the researchers concluded, experience and familiarity can not only soothe the amygdala but bring people's unconscious reactions in line with what they say they believe in: racial equality.

Cunningham, W.A., Johnson, M.K., Raye, C.L., Gatenby, J.C., Gore, J.C., & Banaji, M.R. (2004). Separable neural components in the processing of black and white faces. *Psychological Science, 15*, 806-813.

Lieberman, M.D., Hariri, A., Jarcho, J.M., Eisenberger, N.I., & Brookheimer, S.Y. (2005). An fMRI investigation of race-related amygdala activity in African-American and Caucasian-American individuals. *Nature Neuroscience, 8*, 720-722.

Phelps, E.A., O'Connor, K.J., Cunningham, W.A., Funayama, E.S., Gatenby, J.C., Gore, J.C., & Banaji, M.R. (2000). Performance on indirect measures of race evaluation predicts amygdala activation. *Journal of Cognitive Neuroscience, 12*, 729-738.

Richeson, J.A., Baird, A.A., Gordon, H.L., Heatherton, T.F., Wyland, C.L., Trawalter, S., & Shelton, J.N. (2003). An fMRI investigation of the impact of interracial contact on executive function. *Nature Neuroscience, 6*, 1323-1328.

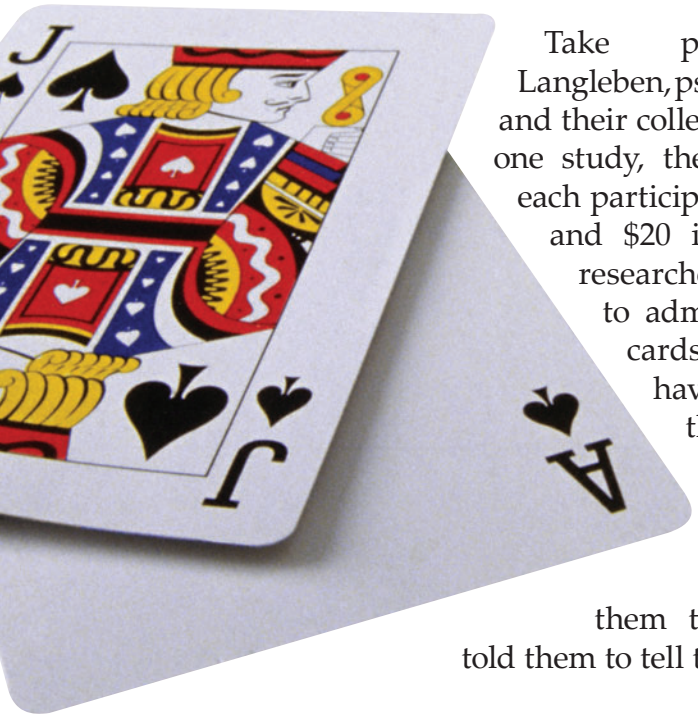
Catching Criminals

When Pinocchio lied, his nose grew longer. If only it were so easy to detect deception in real life.

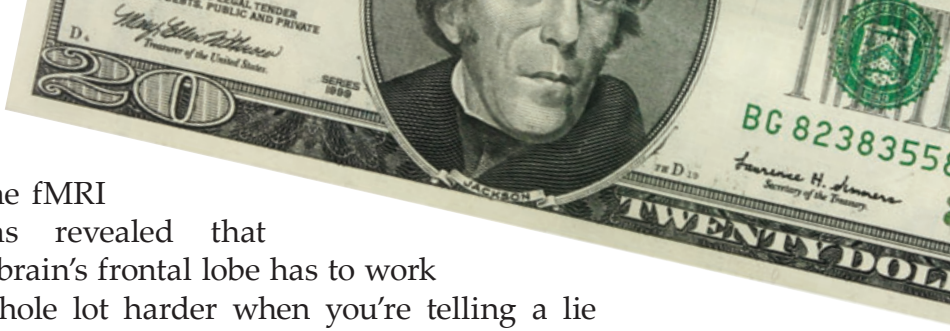
You might be thinking effective lie detectors already exist. Don't believe what you see on television crime shows. The polygraph test—which relies on physical reactions like pounding hearts, heavy breathing, and sweaty palms to determine someone's truthfulness—is widely used.

But truthful people can be so nervous about taking the test that they come across as guilty, while guilty people can be so calm that they're deemed innocent. In 2002, the National Research Council declared that polygraphs are too inaccurate for the government to use to hunt for spies in its midst or to screen potential employees who might be national security risks.

Now psychologists and other behavioral researchers are using fMRI to try to find new—and more effective—ways of telling when someone is lying.



Take psychiatrist Daniel Langleben, psychologist Ruben Gur, and their colleagues, for example. In one study, the researchers handed each participant two playing cards and $20 in an envelope. One researcher told participants to admit having one of the cards but to lie about having the other, adding that they could keep the money if they lied convincingly. To make the lie real, the researcher escorting them to the fMRI scanner told them to tell the truth.



The fMRI scans revealed that the brain's frontal lobe has to work a whole lot harder when you're telling a lie than when you're being honest. Thanks to that insight, the researchers were able to identify lies correctly up to 85 percent of the time.

Of course, all lies aren't alike. There are isolated, spontaneous lies, for instance. Your teacher asks you why you don't have your homework, and you blurt out that your dog ate it rather than admit you simply forgot to do it. Then there's the kind of lie that's memorized and part of an entire story.

Using fMRI, cognitive neuroscientist Giorgio Ganis and colleagues looked at what's going on in the brain during both kinds of lies. They found that the two types activated different brain networks, reflecting the different cognitive skills required by the two types of lies. The findings suggest that lie detection technologies may need to be more complicated than once thought because they may need to accommodate different types of lies.

Researchers aren't just interested in detecting lies, however.

British psychiatrist Quinton Deeley, psychologists Amory Clarke and John Dowsett, and colleagues are trying to uncover the neural basis of the emotional deficits that let psychopaths commit crimes without guilt or any sense of empathy for their victims.

Using fMRI, the researchers scanned the brains of both psychopaths and normal people as they viewed photos of fearful, happy, and neutral faces. When the normal people saw the fearful faces, blood flow to an area of the brain called the fusiform gyrus increased. In the psychopaths' brains, however, blood flow decreased. That atypical brain activity when processing fearful faces may be related to a lack of empathy, say the researchers, noting that fearlessness is another

possible explanation.

The police aren't the only ones interested in all this research. The military, intelligence agencies, even employers intent on finding out whether job applicants have padded their résumés are all eager to put the research to work. Many researchers insist that fMRI-based lie detection isn't yet ready for real-life use, but it probably won't be long before some companies start marketing these services.

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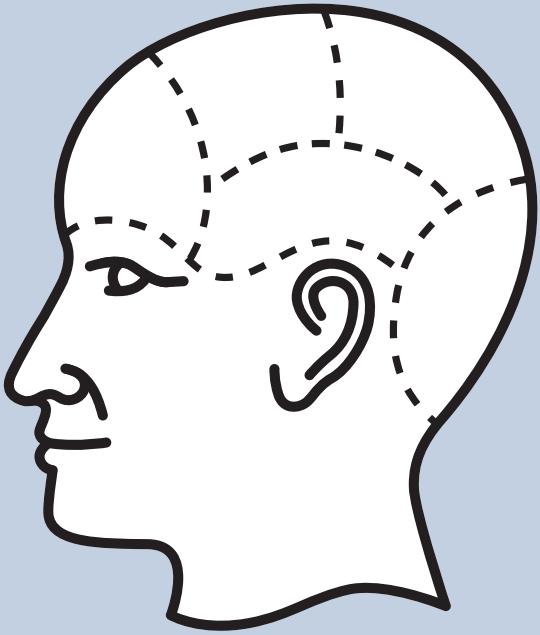
A Bump on the Head

Does the shape of your head reveal anything about your intelligence, personality, or criminality? A 19th century doctor named Franz Gall thought so. According to his theory of phrenology, bumps or dents on the skull indicated over- or under-development of certain character traits. Although skull reading has long since been discredited, Gall and his followers were on the right track: They realized that specific regions in the brain control particular functions.



Exploring the Mind

Making Decisions

Say someone offers to give me $10, and I decide to share the money with you. There's a catch, though: If you refuse to take what I offer, neither of us gets to keep anything. I offer you a dollar. Would you take it?

According to traditional economic theory, your answer should be "yes." You might not consider the offer fair, but one dollar is still more than you would have had if I hadn't offered to share.

But according to an emerging field known as neuroeconomics or behavioral economics, people don't always make rational economic decisions. In fact, many people will refuse an amount they think is unfair, even though that decision means they'll end up with nothing rather than something.

In an fMRI-based study, psychologist Alan Sanfey and other researchers found that this so-called "Ultimatum Game" prompts a battle between reason and emotion in the brain.

Wanting money but resisting unfairness, an area of the brain associated with goals and an area associated with anger and disgust duke it out. When activity in your anterior insula is greater than in your prefrontal cortex, you're likely to reject an unfair offer no matter how much it hurts you economically.

Interestingly, the researchers also found that people were less likely to reject unfair offers if they came from a computer rather than a person.

How your brain reacts to unfairness isn't the only factor that can influence your decision-making without you even being aware of it. How your brain feels about risk also plays a role. Do you take too many risks? Do you go for the sure thing and miss out on potential gains? Or are you somewhere in between?

In one study, psychologist Scott Huettel and his colleagues used fMRI to scan brains as people decided which gambles to take. Some

were guaranteed wins; others were risky. A third category was called "ambiguous," meaning that people didn't have any information on how likely they were to win.

The researchers found that different preferences for risk and ambiguity activated different regions of the brain as people made decisions. Those who welcomed risk had more activity in their brains' posterior parietal cortex, for example. Those who preferred ambiguity had more activity in their lateral prefrontal cortex. The results, say the researchers, may help explain why people make risky choices or help predict how they'll act in certain circumstances.

Such findings don't just interest neuroscientists and economists. Marketing firms are already drawing on such research as they try to figure out how to get people to choose particular brands.

Neuroscientist Read Montague and his colleagues have even used fMRI to find out why consumers prefer Coke to Pepsi.

When study participants sipped soda without knowing which one it was, Montague and his colleagues found, the brands prompted equal reactions in the area of the brain associated with satisfaction. When participants knew which brand they were drinking, Coke suddenly tasted better. That preference was visible in the scans, which showed greater activity in the brain region associated with evaluation and complex decision-making.

In short, a brand can have an impact on your brain!

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Try an Experiment

Ask some friends which cola they like best: Coke or Pepsi. Then offer them a taste of Coke and a taste of Pepsi without letting them see which is which. Can they identify their favorite when they don't see the label? The results may surprise you!

Improving Memory

According to psychologist Daniel Schacter, there are seven memory-related "sins." These memory failures range from absent-mindedness to the gradual erosion of memories over time to actual distortions.

Now Schacter and other researchers are using fMRI to study these memory problems.

In one study, psychologists Jason Mitchell, Chad Dodson, and Schacter focused on misattribution, which occurs when you remember something accurately but misremember when or where you heard it. They examined a form of misattribution called "illusory truth," the tendency to believe things are true simply because you've heard them before. Lawyers and judges are all too familiar with this problem, since juries often base decisions on testimony or evidence they've been told to ignore.

Researchers believe that the illusory truth phenomenon is more likely to occur when people aren't really paying attention to details when they first learn something. When they come across the information again, they recognize that it's familiar but can't remember much about it. In the absence of details, they tend to assume that "familiar" means "true."

To test that idea, Mitchell and his colleagues used fMRI to scan people's brains as they looked at odd bits of trivia—the amount of time it takes to boil an ostrich egg, for instance—projected on a screen inside the scanner. The trivia items were randomly labeled as true, false, or neutral. The researchers later presented the items again and asked participants to recall whether they were true.

The researchers confirmed that what happens in the brain during "encoding" does indeed matter. Participants who had a lot of activity in the region of the brain devoted to recollection when they first encountered the items managed to avoid the illusory truth problem and remember things accurately.

Lawyers frequently come across another type of memory problem:

the fact that eye witness accounts can change over time. Witnesses often change their accounts by adding details they learn after the fact, without even realizing they're doing it.

To learn more about these so-called "false memories," psychologist Craig Stark and graduate student Yoko Okado used fMRI to watch brain activity as they showed people slide shows of situations such as robbery. They then presented a second show with several details changed just a little bit. A few days later, they asked participants to recall details like whether the robber hid behind a tree or a door and to identify which slide show contained the information.

The researchers found that they could use people's brain activity during memory encoding to predict whether their memories would be accurate or not. Participants who remembered the details accurately had more activity in a brain region called the hippocampus during the original slide show; those who remembered inaccurately had greater activity there during the second show. The finding suggests that people with false memories combine bits and pieces—whatever excited the hippocampus the most—into what they believe is a single memory.

Psychologists don't just use fMRI to study how memories go wrong. They also use it to study how people can remember more accurately.

Psychologists Brenda Kirchhoff and Randy Buckner presented study participants with images showing unlikely pairs of objects—a pig on top of a house key, for instance, or a banana in a dump truck—and asked what strategies they used to remember them.

Two techniques proved most successful in helping people memorize things: studying what the images looked like and creating sentences about the objects. These differing strategies showed up as differing patterns of brain activity in fMRI scans. People who used the visual strategy had more activity in the left posterior brain region, for instance, while people who used the verbal strategy had more activity

in their left anterior region.

The researchers' hope? To use what they've learned in training programs to help older people, people with Alzheimer's, or anyone else with memory loss improve their skills.

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